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TOTAL OWNERSHIP COST CONSIDERATIONS IN KEY PERFORMANCE PARAMETERS AND BEYOND

MICHAEL W. BOUDREAU AND BRAD R. NAEGLE

Total Ownership Cost (TOC) is an initiative to manage costs over the entire life cycle of a system, and the Program Manager (PM) is responsible for estimating and managing system TOC using input from key stakeholders. There are several major categories of costs that contribute to TOC. For instance, the phases of a weapon system's life cycle may include research and development, production, operating and support, and disposal. This paper addresses ways to encourage a Life Cycle Cost (LCC) perspective, examine the critical issues associated with understanding and implementing the TOC concept, and assist the PM with the knowledgeable execution of a TOC plan. Also, metrics necessary to ensure appropriate implementation are explored, various methods of controlling and reducing TOC are evaluated, and areas where the Department of Defense needs to refocus are addressed.

Is the Department of Defense (DoD) headed down the right path to get Total Ownership Cost (TOC) under control? There are, no doubt, weapon systems that the DoD procures without regard for the Total Ownership Cost (TOC) as the capability needed is so critical that DoD would pay nearly anything to have it—for a while at least. For example, the SR-71 Blackbird was an extremely effective reconnaissance aircraft, but the Air Force was happy to retire the last of the fleet primarily due to the system operation cost, which was purported to be as high as $200,000 per hour in TOC terms. As shown by this example, the excessive TOC burden of even the most capable weapon system becomes unbearable.

Many useful approaches to grasp the TOC have been advanced by the DoD community over the past several years. Though various techniques have been employed, as appropriate, over the total life cycle of a warfighting system, the DoD has not reached the point where it can declare victory. For whatever reason, the DoD leadership has not mandated the use of some of its most potent tools to get TOC under control.

TOC – WHAT IS IT?

There are two commonly used definitions of TOC. The first is very broad and was written from a top-level DoD or Service perspective:

> DoD TOC is the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and its Components. DoD TOC is comprised of [sic] costs to research, develop, acquire, own, operate, and dispose of weapon and support systems, other equipment and real property, the costs to recruit, train, retain, separate and otherwise support military and civilian personnel, and all other costs of business operations of the DoD (Gansler, 1998).

The second definition is deliberately written from the vantage point of the Program Manager (PM) of the warfighting system and is a subset of the definition above.

> Defense Systems TOC is defined as Life Cycle Cost (LCC). LCC (per DoD 5000.4M) includes not only acquisition program direct costs, but also the indirect costs attributable to the acquisition program (i.e., costs that would not occur if the program did not exist). For example, indirect costs would include the infrastructure that plans, manages, and executes a program over its full life and common support items and systems. The responsibility of program managers in support of reducing DoD TOC is the continuous reduction of LCC for their systems (Gansler, 1998).

As Dr. Gansler said in his above-referenced 1998 memorandum, when trying to reduce TOC, the PM's job is a very difficult one, and the PM should seek help wherever possible to reduce ownership costs. Pursuit of Reduction of TOC (R-TOC) may be separated into two major approaches that are connected, end-to-end, along a life cycle time line. During the developmental phases, the effort or process is called Cost As an Independent Variable (CAIV). For systems in the field or fleet, the process or goal becomes R-TOC. Figure 1 illustrates a typical depiction of the CAIV/R-TOC relationship.

In the first approach, CAIV addresses TOC during the warfighting system's developmental phases, beginning with Concept Refinement. The focus of CAIV is to establish cost targets based on affordability and requirements, and then to manage in accordance with those targets, thereby controlling TOC. CAIV includes consideration of costs for development, production, operations and support, and disposal. For example, the CAIV process would

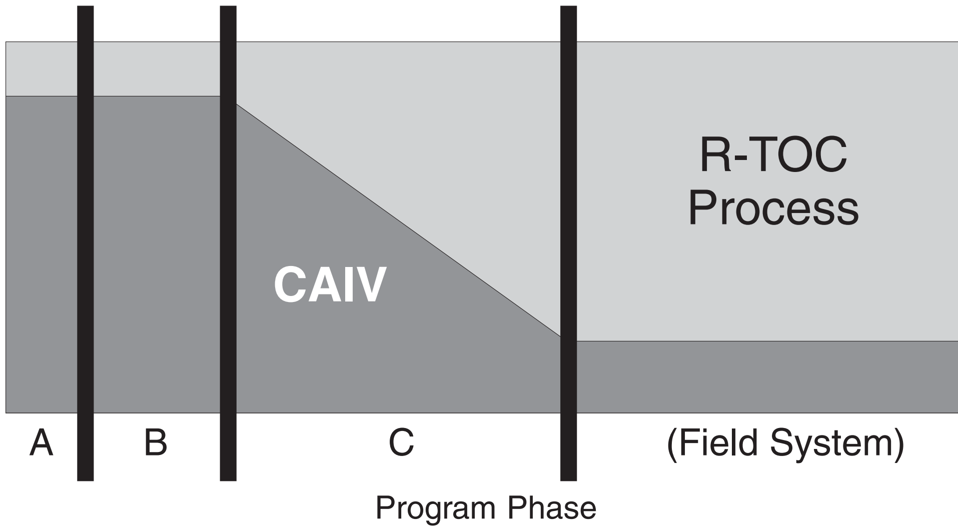

FIGURE 1. COST AS AN INDEPENDENT VARIABLE REDUCING TOTAL OWNERSHIP COSTS

set specific cost and reliability targets for each subsystem or component of a weapon system in development, so the warfighting system will be able to achieve the required operational availability at the specified cost.

During Concept Refinement, a mix of performance requirements and cost constraints would lead to a trade-off analysis, wherein a team, led by the sponsor or warfighter and populated by the stakeholders (sponsor, users, maintainers, and developers), would critically assess the various possible solutions and arrive at the *solution set* that best meets the users' required capabilities within cost constraints. This activity is called an Analysis of Alternatives within the Joint Capabilities Integration and Development System (JCIDS) directives; the Army Training and Doctrine Command has used a very instructive name for the team—Integrated Concept Team (Gansler, 1998; U.S. Army Training and Doctrine Command [TRADOC], 1996).

Employing CAIV early in the developmental process offers the greatest potential opportunity for R-TOC at the lowest possible investment cost. For example, comparison of two different power plants presents an opportunity to use the CAIV evaluation technique to estimate the TOC impact and make a best-value decision. For illustrative purposes, consider a standard internal combustion engine at a cost of $7,500 versus a hybrid electric power plant costing $19,000. The impact to the acquisition cost is evident but excludes the cost savings associated with fuel consumption over the life of the system. If the system's operational mode indicates an average usage of 15,000 miles per year and an economic useful life of 20 years, the total mileage expected is 300,000. If the standard engine is estimated at 10 miles per gallon and the hybrid engine is estimated at 25 miles per gallon, the estimated fuel saved by the hybrid-powered system would be 18,000 gallons. Beginning with an estimated fuel cost of $1.25 per gallon and using constant dollars, the Operating and Support (O&S) impact is $22,500 per system. From a TOC perspective, the hybrid engine is $11,000 less expensive than the standard engine, and there are other reductions in fuel supply assets and attendant personnel that apply.[1]

THE BEST EFFECT—UP FRONT AND EARLY

Capability Documents. Key Performance Parameters (KPPs) are identified within the weapon system's capability documents and represent those minimum attributes or characteristics considered most essential for an effective military capability. Depending on the nature of the weapon system, the KPPs may be validated by the Joint Requirements Oversight Council, the Functional Capabilities Board, or the DoD Component. KPPs that appear in the Capabilities Development Document or Capability Production Document are then inserted, verbatim, into the Acquisition Program Baseline (APB). These KPPs typically represent minimum or threshold performance requirements that are not considered for trade-off during CAIV analyses.

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The KPPs bring the DoD and Service leadership to a crossroads. If CAIV is critical within the DoD, then a forceful way to express its importance is to designate TOC limits as a KPP. In a February 2003 report (GAO-03-57, pp. A-10 & A-11) entitled "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs," the Government Accountability Office (GAO) has recommended use of TOC KPPs as a way to mirror commercial best practices, yet the Office of the Secretary of Defense (OSD) does not require making LCC or TOC a KPP. To be more precise, by its definition of KPP, the Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01C allows, but does not require, LCC to be a KPP (Office of the Joint Chiefs of Staff, 2003). Use of KPPs establishes constraints to possible solution sets and other risks; therefore, KPPs should be kept to a minimum.

A PROMISING EXAMPLE OF THE USE OF KPPs

The Joint Strike Fighter (JSF) provides an example of KPPs that addresses TOC. The JSF has six KPPs; three of the six address supportability/affordability (Hudson, 2003), and are as follows:

1. *Mission reliability* directly impacts O&S costs for parts replacement and the associated expenditure of maintenance man-hours.

2. *Logistics footprint* influences both program acquisition costs and O&S costs; the smaller the footprint is, the smaller the acquisition cost will be and the less expensive it will be to transport and maintain.

3. *Sortie generation rate* depends on maintenance man-hours per operating hour and heavily influences design for maintainability.

These three JSF KPPs have brought about the use of autonomics, which includes on-board diagnostics/prognostics, and have improved the cost effectiveness of maintenance. They also impact affordability and could be at least partially redefined in terms of Average Procurement Unit Cost (APUC) and O&S costs.

THE NEXT BEST TOC OPPORTUNITY—EARLY IN SUSTAINMENT

If TOC is not fully integrated into a system's design during the developmental phases, an opportunity is missed, but all is not lost. This is where R-TOC kicks in. The reality is that programs never get LCC 100 percent right during the development phases. The R-TOC provides the process *tool box* for working on cost improvements once the warfighting system is in production and/or sustainment.

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The R-TOC focuses on the reduction of APUC and weapon systems sustainment costs (i.e., the O&S costs). It is employed while the warfighting system is produced and placed in service; during this time, the cost drivers are identified and isolated. Two examples of R-TOC illustrate how the Value Engineering Change Proposal (VECP) is used. One use might be to reduce the cost of manufacturing a component by improving the process yield (the percentage of the manufactured item that is defect-free); another might be to reduce the O&S costs by improving the reliability of an expensive subsystem or component. Often R-TOC initiatives result in secondary benefits that enhance performance (i.e., improved reliability and operational availability); however, the forcing function is generally the reduction of O&S costs, the largest constituent of TOC for most systems.

Operating and Support Costs. The O&S phase includes most sustainment and administration costs incurred during the weapon system's operation in the field or fleet (e.g., repair parts or the labor cost associated with engine repair). It also includes labor costs for uniformed and civilian personnel. Operations and Maintenance (O&M) appropriations pay a large part of O&S costs (including civilian personnel but not military personnel) and pay for disposal costs as well (Department of Defense [DoD], 2003).

O&S costs may be dramatically reduced by identifying O&S cost drivers (i.e., those components that, through Pareto analysis, are recognized as major contributors to the cost of the operation) and correcting them often, but not always, through redesign. The most efficient time to accomplish this is during the preacquisition and predevelopment phases (i.e., when the system is only a paper design and can be changed relatively inexpensively). However, cost drivers that are discovered during the production and sustainment phases may also lead to redesign or other actions that can save or avoid significant expenditures. The DoD pilot programs exhibit many useful examples of R-TOC, such as the Abrams Tank engine Partnership for Reduced Operation and Support Cost Engine (O&S) Costs (PROSE), the SH-60 Affordable Readiness Initiatives, Aviation Support Equipment Reliability Improvement Initiatives, the EA-6B Inertial Navigation System, and the SLAM-ER Data Link Pod (Institute of Defense Analyses, [IDA], 2005).

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A HIGH-PAYOFF EXAMPLE OF THE USE OF R-TOC

The AEGIS system (U.S. Navy phased array radar-based combat system) provides an example of a very successful R-TOC effort, which began in the mid-1980s and is still paying off like a *gilt-edged bond* today. Each ship requires microwave-producing equipment that includes a device called a Crossed-Field Amplifier (CFA). Early in AEGIS deployment, the CFA proved to be a cost driver with relatively expensive failures attributable to an arcing condition between the cathode and anode in the microwave tube. This arcing caused the CFA to fail at about 6,000 hours Mean Time Before Failure (MTBF). A change to anode metallurgy, along with other minor changes, reduced arcing and increased MTBF to between 40,000 and 45,000 hours. These changes drastically reduced the frequency of corrective maintenance, maintenance man-hours, stockage-level requirements, and also simultaneously improved the reliability and availability of the microwave system. This dramatic improvement was the result of a team effort among the AEGIS Program Office, Communications and Power Industries (CPI) (vendor that provided the CFA and was formerly part of Varian), Crane Naval Surface

Warfare Center (the Navy In-Service Engineering Agent for AEGIS microwave tubes), the Navy ManTech Office, and Raytheon (the prime contractor, located in Sudbury, MA). This R-TOC affects 27 AEGIS cruisers, each having 76 CFAs; and 40 AEGIS destroyers, equipped with 38 CFAs. In 2002 dollars, the annual cost avoidance averaged about $1.9 million per AEGIS cruiser and $950 thousand per AEGIS destroyer. Eventually, the R-TOC will benefit an additional 22 AEGIS destroyers, which are yet to be completed and deployed; each will have 22 CFAs (K. Hoffer, personal communication, November 17, 2003).

TOOLS, TECHNIQUES, AND CONCEPTS SUPPORTING EFFICIENT TOC SOLUTIONS

As a system progresses from early concept through prototyping and production and finally reaches the sustainment phase, the opportunities to significantly reduce TOC diminish. Clearly, TOC reduction efforts are most effective early in the developmental cycle, when changes are the least expensive, easiest to implement, and have the widest effect. Looking from the perspective of the warfighter, the possible effect of a balance between capabilities and affordability is that *more warfighting assets may be available to the warfighter*. To that end, TOC stakeholders have a vested interest in influencing the system design and development, especially early in the process, so a suitable, effective, and *affordable* solution will be generated. The challenge is how to accomplish this goal.

One answer to this challenge was postulated earlier—make TOC goals part of the system's KPPs. One of the only methods of keeping the TOC goals from being in the *trade-space* for CAIV or other trade-off analyses is to designate those goals as KPPs. As with other KPPs, a TOC KPP would be considered as a mandatory threshold, and the use of other tools and techniques would then serve to reinforce the importance of TOC. Since KPPs are also part of the APB, TOC would receive attention from decision makers at every level throughout the developmental process.

CAIV and Other Trade-off Analyses. With a firm understanding of the performance characteristics (hopefully including TOC) that the warfighter deems critical to the system's effectiveness and suitability via the KPP, CAIV analysis techniques can be used to reduce the TOC of subsystems, features, and capabilities in the *trade-space* (i.e., items not identified as KPPs). These analyses serve the materiel developer in balancing system capabilities, technologies, schedules, and costs within the parameters set by the sponsor. Proper identification of performance parameters and closer connectivity between the materiel developer and sponsor will help ensure that the developed system is effective, suitable, and affordable.

Integrated Product Teams (IPTs). Cost-Performance IPTs (CPIPTs) play a key role in trade-off analyses that impact TOC, and other IPTs can, and should, participate in reducing costs as well. By their nature and in accordance with their charter, IPTs solve problems and make recommendations based on their research of a particular program aspect. If each IPT charter includes the goal of reducing TOC within its area of concentration, significant opportunities for TOC reduction could be captured.

In addition to cost trade-offs that occur in the CPIPT, other trade-off analyses may reduce system TOC. For example, a high-maintenance, low-availability, and cutting-edge system that is not a KPP requirement might be traded-off or deferred to a future block upgrade, allowing the technology to mature, reliability to improve, and LCC to be reduced. Schedule trade-offs, while often considered negative, may allow software engineers to more fully test and integrate a critical software function and eliminate frustrating downtime and costly diagnostics. Both of these trade-offs would likely result in reduced TOC.

It is important to recognize that cost-performance trade-offs may reduce TOC at the price of reduced performance. In this regard, the warfighters—the real users of the systems—must be involved in the process to ensure that the solution set is acceptable and that it balances warfighting capability and O&S cost, which are typically borne by the warfighter.

Ownership Cost Databases. Due to the lack of reliable information databases, we are currently limited in our understanding of LCCs for our legacy systems (IDA, 2005). Without that knowledge, we are limited when estimating the impact of TOC reduction efforts on those LCCs. Asking a program office how much it will save by an R-TOC effort is rather like asking a person the distance of the path he or she *didn't* take and comparing it to the one taken. Someone else certainly has traveled the other path, but there is simply no record of it. Establishing Reliability, Maintainability, Sustainability (RMS) cost databases may seem an expensive initiative, but the knowledge gained from capturing sustainment costs would help focus R-TOC efforts, influence the design of future systems, and thus bring about a better balance of capabilities and affordability.

Contract incentives…VECPs, shared savings from cost reduction initiatives, and other incentives motivate contractors to perform in a manner that enhances their profit and reduces TOC of the weapon system—a true "win-win" situation.

Contractor and Government R-TOC Incentives. The profit incentive present in the commercial marketplace provides the DoD with a powerful tool for reducing TOC. Contract incentives (e.g., improving reliability, increasing MTBF, and reducing maintenance cycle time), Value Engineering Change Proposals (VECPs), shared savings from cost reduction initiatives, and other incentives motivate contractors to perform in a manner that enhances their profit and reduces TOC of the weapon system—a true *win-win* situation. In the sustainment phase, improvements are possible, and there are many good examples from the TOC Pilots (IDA, 2005). However, the *home runs* in TOC reduction are more likely to occur prior to production rather than afterward.

Source selection criteria shape how contractors compete for development, production, and Contractor Logistics Support (CLS) contracts; therefore, TOC elements in the Source Selection Plan positively impact proposals that contractors submit. In the case of public-private competition or partnerships for logistics support contracts, the same concept applies—the winning bidder must present the most advantageous proposal, and the source selection criteria must define those parameters. Selecting key TOC elements as source selection criteria ensures that the competing entities focus on methods of achieving TOC efficiencies to gain advantage over other bidders.

TOC incentives for Government sponsors[2] and materiel developers have been less effective than desired (GAO, 2003). While TOC is obviously important to the combat developer and user community, it seems that more emphasis has been placed on emerging warfighting capabilities and modernization efforts than on TOC performance in the early stages of development: stakeholders are more interested in *what the weapon system will do* than *what it will cost to do it*. After introduction to the field or fleet, TOC has typically become an issue, and R-TOC efforts have been initiated in response—precisely at the point in development where such efforts are becoming more costly and less effective.

...R-TOC initiatives can increase military effectiveness when evaluated on their own merits and not coupled to other interests, such as increased system capability.

Following suit, the materiel developer communities focus on those APB elements, including KPPs specified by the sponsor in the capability documents. With little TOC emphasis passed from the sponsor in the defining capability documents, materiel developers have the incentive to focus only on the *acquisition cost*, program schedule, and specified performance, while ignoring potential impacts on operating and support cost. The reason materiel developers are focused on the acquisition costs is that the program and budget elements they manage are typically research, development, test and evaluation and procurement funding, which relate primarily to the acquisition cycle; but these accounts represent only about 25–30 percent of the TOC. Except for TOC-related KPPs, TOC elements inevitably drop into the *trade space* for managing the acquisition cost, program schedule, and performance identified by the combat developer. This tendency often suboptimizes TOC by trading off features/functions (resulting in higher O&S costs) in favor of lower acquisition cost, even though O&S costs consume about 70–75 percent of TOC.

Reduction in Total Ownership Cost (R-TOC). Although R-TOC initiatives are more effective and less costly when performed early in the development cycle, TOC reduction still can be beneficial throughout the system's life cycle. Confirming through cost-benefit analyses, that R-TOC initiatives will reduce cost, these initiatives are likely to increase the warfighter's capabilities. Having more funding available in the acquisition phase or in the O&S phase will either provide more assets directly (acquisition phase) or buy increased readiness rates (O&S phase). Therefore, R-TOC initiatives can increase military effectiveness when evaluated on their own merits and not coupled to other interests, such as increased system capability.

CONCLUSIONS

1. Up-front planning can result in major TOC savings, but JCIDS offers little emphasis on CAIV and R-TOC at the front end of the process (i.e., in Concept Refinement and Technology Development phases). Current guidance permits TOC to be designated a KPP, but this is not required.

2. Serious consideration must be given to elevating TOC to KPP status. This will go a long way to avoid trading off TOC during the developmental process. Joint Strike Fighter (JSF) certainly offers an example of creativity in treating TOC as KPP.

3. There are many success stories several of which are documented in TOC pilot programs that might be beneficial to other acquisition programs, especially legacy systems. The R-TOC success hinges on finding the cost drivers and addressing them with innovative R-TOC solutions. Limited funding hinders aggressive action to redesign components that are cost drivers.

4. Tools and processes are generally available, with the exception of complete and integrated cost databases. Without complete, easily retrievable cost data, it is difficult to identify cost drivers and recognize components or warfighting systems that need to be redesigned to reduce TOC.

5. The real question is: Does the DoD leadership have the will to demand that TOC be addressed seriously?

Colonel Michael W. Boudreau, USA (Ret) has been senior lecturer at the Naval Postgraduate School since 1995. While an active duty Army Officer, he was Project Manager, Family of Medium Tactical Vehicles. He commanded Materiel Support Center, Korea, and Detroit Arsenal Tank Plant. Boudreau is a graduate of Industrial College of the Armed Forces, DSMC, and Army Command and General Staff College. He holds mechanical engineering and MBA degrees from Santa Clara University, California.

(E-mail address: mboudreau@nps.navy.mil)

Lieutenant Colonel Brad R. Naegle, USA (Ret) is the academic associate for Program Management Curricula at the Naval Postgraduate School (NPS). On active duty, he was the Program Manager, 2½ Ton Extended Service Program and the Deputy Program Manager for Light Tactical Vehicles. He holds a master's degree in systems acquisition management from Naval Postgraduate School and a bachelor's degree in economics from Weber State University. He is a graduate of the Command and General Staff College and Combined Arms and Services Staff School.

(E-mail address: bnaegle@nps.navy.mil)

AUTHOR **BIOGRAPHIES**

AUTHORS' NOTES

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ENDNOTES

1. This example is calculated in constant dollars to provide an accurate cost comparison; this is a practice typically used in DoD cost estimation. For budgetary purposes, constant dollars would have to be inflated in future years to take into account that the dollars used in future years are incrementally less valuable than the dollars used in earlier years (i.e., the time value of money).

2. The term *sponsor* is consistent with CJCSI 3170.01C. Sponsor supercedes the term *combat developer*, which may still be used in some DoD communities.

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